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Year 1 Progress Report
NASA Award Number, NNX07AL32G,
"INTELLIGENT SENSOR NETWORK STUDY OF DUST DEVILS"

May 2007 - April 2008

An array of 20 PICAXE dataloggers procured previously were assembled together with pressure, temperature, light and microphone sensors. BASIC code was written to perform sampling and readout on the dataloggers, including selective averaging and bias subtraction on-board.

The datalogging array was deployed in a short field trial in September 2007, at the tail end of the summer dust devil season. A good encounter was captured on 18 of the 20 loggers and preliminary results were presented in a poster and extended abstract at the Lunar and Planetary Science Conference in Houston, TX in March 2008. Several areas for improvement in the datalogger code have been identified.

To provide documentation for the meteorological record, some initial experiments with digital timelapse cameras (controlled by PICAXE microcontroller, and thus ultimately event-triggerable rather than just timed) have been conducted and show considerable promise.

In addition to the Tucson dustdevil field tests (confined to the summer months, for obvious reasons) we also conducted a three-month trial deployment of several types of datalogger at Death Valley National Park (Racetrack Playa) where very occasionally winds are able to move large rocks across the muddy playa. A paper has been submitted to the journal 'Geology' on the rock budget and transport rate that motivates the field study.

These dataloggers were successfully recovered from the playa and give unprecedented insight into the highly variable conditions at the playa, and a journal paper is under preparation.

An array of 20 wireless motes (Crossbox Mica-2) has been procured for future field experimentation in the May/June dust devil season and are presently under laboratory evaluation. These will have broadly similar sensors to the PICAXE loggers, but will permit wireless downloading of data (saving time, once familiarization with the motes and their operating system is attained) as well as experiments in inter-mote communication.

Additional field deployments in Tucson and Death Valley are planned in the next year (in summer and winter respectively) with both the motes and improved PICAXE loggers.

Attachments:
LPSC Conference Abstract describing PICAXE array observations of Tucson dust devil
Geology paper manuscript submitted on Racetrack Playa rock movements

A 20-STATION ARRAY OF INTELLIGENT DATALOGGERS TO STUDY TERRESTRIAL DUST DEVILS : PRELIMINARY TRIALS. Ralph D. Lorenz JHU Applied Physics Lab, 11100 Johns Hopkins Road, Laurel, MD 20723, USA. email: ralph.lorenz@jhuapl.edu

Introduction: The 2-D horizontal structure of dust devils is not well-understood, since data in most studies so far is acquired from a single (fixed or moving) station. Sampling bias from truck-mounted surveys which of necessity chase the largest, dustiest devils calls into question some of the statistics of physical properties such as pressure and dust loading. Here I report initial efforts to study dust devils with an array of many small, intelligent dataloggers, generating an entirely new class of dataset for the study of this phenomenon.

Trial: A field trial with an initial array of 20 dataloggers (based on the PICAXE-18X microcontroller, programmed by the author in BASIC) was conducted in September 2007, northwest of Tucson, AZ. Each logger (with a parts cost of <$100 including sensors) measures pressure, light level, temperature and a passive microphone (used as a proxy for turbulent wind intensity) once a second for an hour.

The logger program can be revised in the field if necessary : presently it performs selective logging and digital signal processing (storing time-tags once every 100 records, rescaling the temperature and light level sensors to maximize the utility of each 1-byte measurement; averaging of several 10-bit pressure reading and rescaling into 1 byte, and recording the total of the differences between successive microphone samples, rather than the absolute value.)

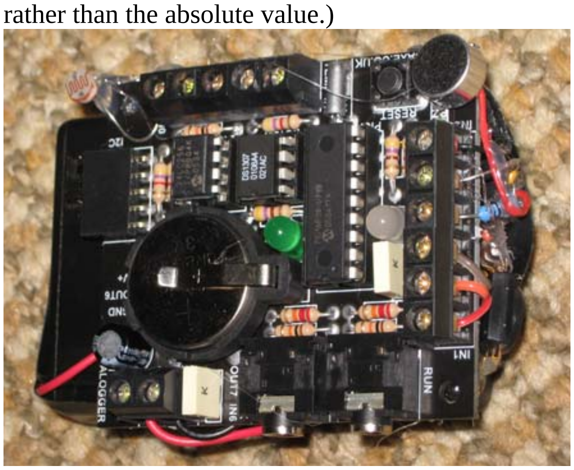

Figure 1. A photo of one of the loggers, little bigger than the 3 AA cell power supply underneath.

The array was deployed in an E-W line (although 2-D deployments can of course be envisioned in future) with stations separated by ~3m. The array was broadsided by a large dust devil after ~30mins. After the 1-hr acquisition period the array was recovered and data downloaded to a laptop via serial cable (two loggers failed to return good data.)

Figure 2. Image of the dust devil documented in this report.

Results: The sensor suite (Freescale pressure, DS1820 temperature, CdS LDR light sensor and electret microphone) is chosen for low power and low cost. Nonetheless, all of the elements appear to give useful signatures of the dust devil and the software-controlled datalogging was successful (although only partially so in the case of the pressure record.)

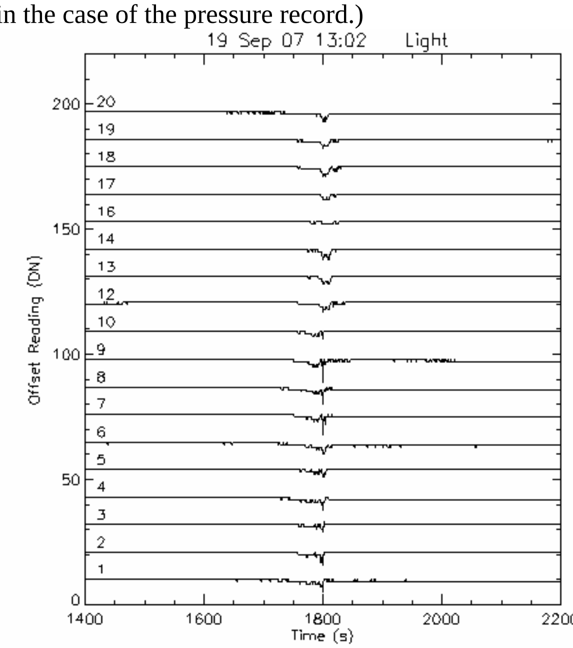

Figure 2. The passage of a dust devil is recorded in the light level record of all of the 18 operating dataloggers (data from loggers 11 and 15 was lost).

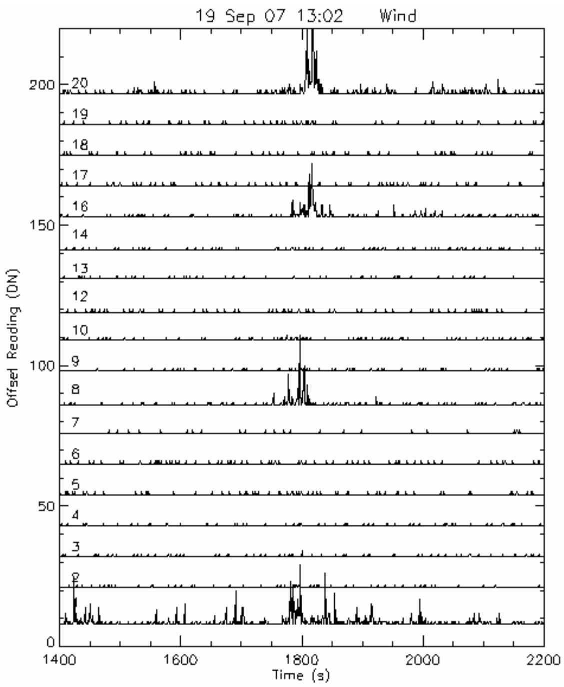

Figure 4. Passive microphone indicates wind: it is not yet understood why this signal appears only on 4 widely-separated loggers and not on the others.Record shown is the sum of differences between 20 readings and thus indicates fluctuations in dynamic pressure.

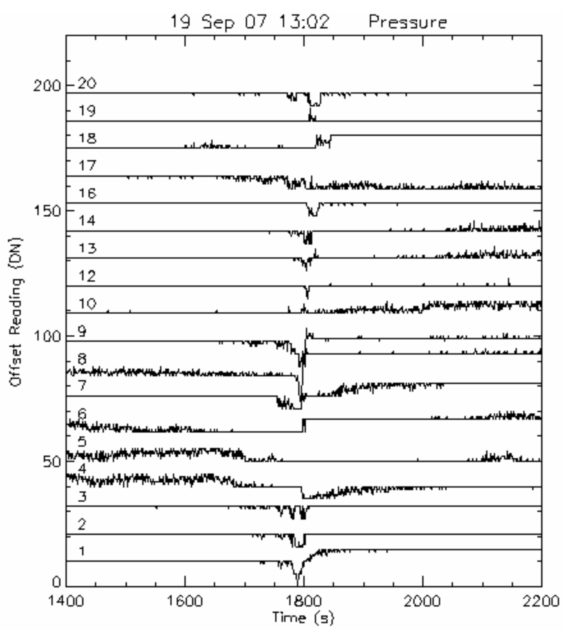

Figure 5. A pressure perturbation can be discerned on 12 of the 18 loggers : unfortunately a coding error resulted in clipping of data so some loggers missed the pressure event due to a slowly-changing baseline.

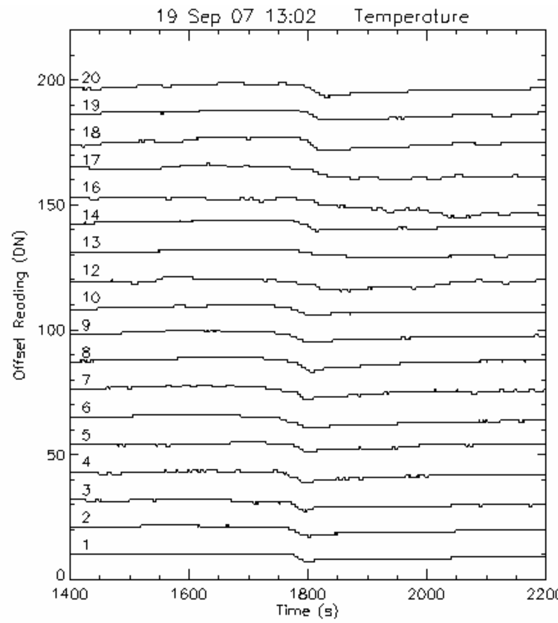

Figure 6. The temperature of all loggers dropped and in most cases did not recover fully – presumably due to deposition of bright dust changing the radiative balance of the loggers.

The large size of the devil was paradoxically inconvenient, in that the whole array was stimulated, rather than allowing the array to define a 'size' of the devil. Inspection of the data shows clear signatures and suggests that simple rule-based event detection can be implemented on the PICAXE microcontroller. This opens the way for much longer surveys, and possibly intelligent arrays wherein one sensor triggers the others.

Conclusions: These initial results show considerable promise : it is believed that these simultaneous records of many locations across a single dust devil are unprecedented. Field trials in summer 2008 with a more capable array are planned. The microcontroller approach has proven to be versatile, capable of generating useful statistics of sensor readings rather than merely recording the raw values.

The trials identified several areas for enhancement. These include automating or at least streamlining the data download process, perhaps wirelessly. Synchronization of the array records requires some effort, and GPS receivers are now becoming sufficiently affordable to make that a viable option. Increasing memory storage and/or implementing on-board event detection will allow much longer observation periods, even at higher sample rates.

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1/29/07

The Disappearing Rocks of Racetrack Playa : The budget of rock supply and removal.

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Abstract

The famous sliding rocks of Racetrack Playa are considered from a process perspective : the inventory of rocks on the playa represents a snapshot of the balance between the discontinuous processes of rock supply and removal. Examination of prior rock inventories and documented movements suggests that the present-day typical residence time of rocks on the playa is roughly one century. The size distribution is bounded by two power laws and points to more rapid removal of smaller rocks and that transport and/or burial, rather than fragmentation, are the dominant removal processes. The spatial distribution of rocks is simulated with a stochastic model, which suggests that the present population does not represent an equilibrium between the southern cliff source and uniform removal rate across the playa : either removal rates are spatially nonuniform, or the rock supply rate has been higher in recent decades than is balanced by the present transport rate, or both. Environmental factors that may affect these rates are considered in the light of climate change, and possible future studies are discussed.

1. Introduction

Racetrack Playa in Death Valley National Park, California is a 4.5x2km lakebed at an elevation of 1130m, only occasionally flooded. It is exceptionally flat (the south end is only a few cm lower in elevation than the north) and is of mixed sand-silt-clay composition, usually with striking but small dessication polygons. It is distinguished by the presence of some dozens of rocks (usually cobbles or small boulders) which are very distinct against the very uniform playa (figure 1), and often appear at the end of trails or furrows in the playa surface. These trails suggest that the rocks have moved across the surface at some speed when the playa was wet.

Much attention has been directed towards documenting the rocks and their movements (e.g. Kirk, 1952; Sharp and Carey, 1976; Reid et al., 1995), and to speculating (observations are sadly lacking) upon the mechanism by which they are induced to move, presumably by wind, e.g. Schumm (1956). However, the mechanism of the rocks' motion is only one aspect of the playa rocks as a dynamical system, consideration of which raises several further questions, not least, 'where do the rocks go?'. The counterpoint, of where the rocks come from, is more readily answered. In the definitive survey of the playa, that by Messina (Messina 1998; Messina and Stauffer, 2000), some 92% of the 130 rocks counted are a dark grey dolomite that comes from cliffs that extend onto the southern edge of the playa. It is proximal to these cliffs that the highest abundance of rocks occurs. Little consideration has been given heretofore towards the rate at which the cliffs supply these rocks.

While Sharp and Carey (1976) dismiss study of the playa rocks as 'hardly matters of greatest scientific import' before going on to present a rather detailed investigation motivated by 'broad interest in this curious phenomenon', we show here that in fact the playa rocks may be a sensitive indicator of the relative rates of geological processes, and therefore possibly a bellweather of climate change. There is rich and interesting physics at work and serious study is merited from both a research and pedagogical perspective.

In this paper we first summarize the rock inventory and the rate at which the rocks have been documented to move in prior works (by recording their position at visits on different years and/or by measuring trails in the playa surface). The rocks move in directions which can vary locally (some trails even showing loops) but in general are northwards , and thus they should traverse the playa sooner or later unless destroyed or buried. That being the case, the traverse time will correspond to a typical residence time of a rock. We consider the inferred residence time of ~100 years to alternative rock removal processes, and compute a rock delivery rate assuming the rock production delivers the observed inventory in that period. The size distribution is considered quantitatively and reveals the different size-dependencies of supply and removal. Next, we consider the spatial distribution of the rocks, and explore what this might mean for variability of the source and sink terms of the rock flux under different conditions. We close with a summary and suggestions for future measurements.

2. Rock Inventory and Residence Time

The playa is about 4km long by 2.5km wide (see figure 2). The distance from the two cliffs at the south to the playa edge in the predominant transport direction (NNE) is a little over 1km, but given the uncertainties in other processes, we will adopt that round figure for the residence time estimate.

Sharp and Carey (1976) document some 30 or so rocks and their movements over 3 intervals in the period 1968-1974. Their movements were recorded by directed measurement relative to reference stakes inserted into the playa (a practice that would not be presently permitted.) The selection criteria for the 30 rocks are not documented adequately to infer what the total population on the playa might have been. However, from the data recorded in their paper it can be calculated that the average motion over the 6 year period was about 70m, or ~10m/yr. However, this 70m is the vector sum of discrete movements – not always parallel – in the intervening years, and many rocks in many years did not move at all. The mean of the non-zero movements is about 35m, and movements thus occur once every two to three years. If the 70m per 6 winters is representative, and if transport across the playa is the mechanism by which rocks are removed from it, then it therefore take rocks roughly a century to traverse the playa to the other side, depending on the transport direction.

The average trail length documented by Messina (1998) was some 200m, and there was an average of 8 turns per trail. It seems reasonable to associate a single straight segment of a trail as a single movement event, and since it may well be that on those seasons when movement occurs, more than one movement can occur, a movement per event of (200/8)=25m is not in violent disagreement with a movement per season (when movement occurs) of 35m from Sharp and Carey's data, and thus the trail length data also appears consistent with a traverse time of order 100 years.

Some additional trail length data was recorded by Reid et al. (1995). They documented two movement events in seven visits between 1987 and 1994. They mapped over 20 rock trails with an electronic

theodolite, and noted substantial coherence between many trails (arguing that the congruence of trails separated by hundreds of meters implied that those trails at least had to be made by rocks locked together in a sheet of ice, a hypothesis originally due to Stanley, 1955.) Specifically, seven trails of total length ~200m, giving start-to-finish displacement of 135m occurred in the late 1980s, and six trails with length and displacement both roughly 50m occurred in 1992-1993. While some rocks may indeed move in ice sheets, much other work (indeed going back to Clements (1952)) suggests that rock movement can occur without ice. Whether or not ice is involved is not important here, however. We may note that Reid et al.'s data is consistent with movements occurring on one year in three, and that many movements must occur together.

Messina's 1996 survey (Messina, 1998; Messina and Stoffer, 2000) appears to identify 17 of its 140 rocks with those in the Sharp and Carey (1976) study of 31. Thus over 22 years since Sharp and Carey's last visit, 14 rocks are known to have disappeared. If we assume that the overall rock populations were the same in 1974 and 1996, then we can assume that Messina's 130 can be considered a rather complete inventory and thus this represents 10% of the total.On the other hand, we know that the population in 1974 was at least 31, so at most ~45% of the population was lost. A 10-45% attrition over 20 years corresponds to a half-life of 25-150 years, in reasonable agreement with the century-long transit time estimated above. Even during Sharp and Carey's survey, some 6 of the 30 rocks were lost.

3. Rock Removal and Supply Processes

Here we consider three geological removal processes (human intervention is an obvious fourth possibility, but this is more likely to be a rock source term than a sink). The first mechanism, supported by Sharp and Carey's observation that there were many rocks at the edge of the playa (point C on figure 2) is that rocks simply accumulate at the edge of the playa – their movement can only occur on the flat, wet playa surface, and so they stop when they hit the edge. They may remain visible there, or they may progressively break down, or more likely are engulfed by the large alluvial fan that spreads onto the playa from the east, and thus onto the edge of the playa where most transported rocks are likely to accumulate. If the rocks being transported down on the fan can be discriminated lithologically from those sliding across the playa, it might be possible to assess the relative rates of rock transport and alluvial deposition.

A second possibility is burial on the playa. Since the playa is a closed basin, fluvial action will tend to accumulate fines in it. Messina's survey indicates 130 rocks with heights from 3cm to 57cm – over half of these (the fraction <10cm deep) would be buried in a century if silt and sand were deposited at a rate of 1mm/yr. Sediment delivery will of course depend on the characteristics of the catchment basin, but infill rates of 6 m3/hectare/yr – i.e. 0.6mm/yr – have been documented in playa elsewhere (Coronato and del Valle, 1993). Whether this is a viable mechanism for significant loss remains to be determined – no almost-buried rocks have been documented, although rocks are not uncommonly seen to be embedded in a couple of cm of playa mud. It may be that removal of fines from the playa by wind (as evidenced, for example, by the climbing dune to the north of the playa, and the dust storm noted by Messina (1998)) means that there is no net accumulation of fine sediment.

Finally we examine the possibility that rocks break down on the playa. Some rocks on the playa are seen to have joints or cracks, and of the 12 rocks documented by Kirk (1952) two had nearby fragments (a 30kg rock had 15-20 fragments and a 60kg rock had 6.) However, in-situ fragmentation, without associated removal, would lead to a much higher abundance of small fragments, which is not observed, see next section. Thus while fragmentation occurs, it is not the principal means of removal of rocks from the playa. Sharp and Carey (1976) note most stones are ‘little modified by weathering or transport’.

Thus transport appears to be the dominant removal mechanism. As for rock supply, this appears predominantly due to weathering from the dolomite cliffs at the south (some smaller rocks – e.g. ‘hundreds of fist-sized granitic rocks ‘ near the Western rim (Kirk, 1952) – also appear, presumably brought down from nearby mountains across the alluvial fans that bound the playa, but are not representative of the slider population.) If we take the 140 rocks with a total volume of 1.8 m^3 in Messina’s survey as a century’s worth of rock production then this implies a production rate of one or two rocks a year, totaling about $2m^3$/century. Now, if we take the cliff area at which rock production occurs as $100x20m=2000m^2$, this production rate corresponds to a recession of the free face of 10mm per millennium. This is in fact on the low end of present-day free-face retreats (e.g. Goudie, 1995) which span around 10-1000 mm/millennium. Some factors at work here are the low precipitation at this location, and the likelihood that the rocks that are recognized as such on the playa are only a fraction of the material weathering out of the cliff. The talus slopes have plenty of soil (Figure 1), indicating that fine-grained material is produced – this material is presumably washed or blown away at intervals, but is not recorded in the rock inventory on the playa, and thus the actual cliff retreat may be higher than indicated above.

4. Rock Size Distribution

Messina’s catalog (1998) has a peak clast size of large cobbles ($2,000cm^3$ – $16,000cm^3$, N=70) with rather smaller numbers of clasts in the size decades above and below this range (N=18 and 41 respectively). However, there are enough rocks here to count in rather narrower bins, revealing the distribution shown in Figure 3. This is interestingly bounded by two power laws, which may reflect the competing size-dependencies of supply and removal.

The large-size part of the distribution appears supply-side dominated. It has a differential power-law slope $dN(V)/dV = AV^{-x}$ where A is a constant and x is an exponent of 0.5 to 0.66. This exponent is characteristic of the size-distributions from low-energy fragmentation of rocks without additional sorting (Hartmann, 1969 : strongly comminuted sediments such as those from explosion craters, glacial till etc. would have higher exponents ~0.9). If the -0.66 power law were continued to small sizes, there should be thousands of small pebbles.

However, what is observed is that there are only few pebbles and the small-size distribution has a positive slope of about 0.3. This implies that the rock removal processes are vastly more effective on small particles. Specifically, to deplete the $V^{-0.66}$ population to a $V^{0.33}$ one requires a removal rate inversely proportional to volume, which is to be expected when strong gusts are very rare.

5. Spatial Distribution and indication of Disequilibrium

It is clear from figures 1 and 2 that rocks are most abundant at the south end of the playa – as also noted e.g. by Kirk (1952) and Sharp and Carey (1976), consistent with the cliffs being the source of the rocks. If rocks simply diffused away at a constant rate in all directions, there would be a circularly-symmetric distribution of rocks with a density falling off as the reciprocal of distance from the source.

Clearly, a more complicated pattern is observed (figure 2). We can explore the spatial distribution of the rocks with a computer model. Rocks can be introduced onto a virtual playa and transported in a stochastic manner by rules. By adjusting the spatial and temporal aspects of the rock delivery, and the transport rules, various spatial distributions can be generated. We emphasize that these initial modeling efforts are intended for exposition rather than as an attempt to reproduce the observed distribution.

We construct a 500x1000 grid with 5m spacing, and introduce some number of rocks onto the playa, distributed on an arc centered on the cliff at coordinates (290,120). At each timestep (one year) motion occurs or not (with a probability of 50%, based on section 2). If motion occurs, half the rocks are selected and are displaced a distance Xm, where X is logarithmically distributed between 1 and 200m ; the azimuth is uniformly distributed over a specified arc. Figure 4 shows the resultant evolution of the rocks as a function of time, and with different motion arcs. Clearly different rules give different distributions. Notably, if rock supply is not uniform in time, transport across the playa is slow enough that the playa has some 'memory' of the supply history – the concentration of rocks in figure 2 may be indicative of this effect suggesting that the recent rock supply rate exceeds removal. Also, if the rocks are allowed to move at all westwards, we would expect to see far more rocks in the northwest part of the playa than are observed.

Such a model can be made arbitrarily sophisticated, to include size-dependent and location-dependent transport rates (e.g. winds might be expected to be stronger towards the center of the playa; the southern end of the playa will be flooded more often than the north, and so-on). Nonuniform wind azimuth distributions would be another obvious factor to include - Messina and Stauffer (2000) have heuristically described the pattern as the product of two dominant wind directions. However, it seems that more data (e.g. multiple surveys) would be required for such additional degrees of freedom to be meaningfully constrained.

6. Implications of climate change

The playa itself, and (as we have shown here) its rocks, are the product of its geological and meteorological setting. While the geology will remain more or less invariant over human timescales, the meteorology may not, and indeed extreme environments such as Death Valley have been suggested as being particularly sensitive to climate change.

One possible consequence of global warming is an increase in the frequency of severe precipitation (since a warmer atmosphere can hold more moisture.) This may increase the mobility of the rocks in that the playa may stay wet for longer due to a larger instantaneous water volume. Additionally, the playa may stay wet for longer due to reduced evaporation rate. Evaporation from water pans (e.g. Ohmura and Wild, 2002) depends on solar flux, windspeed and humidity, as well as absolute temperature, and at present the pan evaporation rate(which probably describes playa evaporation rather better than the more complex evapotranspiration loss over many land surfaces) appears to be generally declining.

Another possible effect arises via the dependence of rock generation on freeze-thaw cycling (e.g. Bland and Rolls, 1998). A well-documented feature of present climate change is that the night-time low temperatures are rising faster than the day-time highs. Thus the frequency with which freezing conditions occur is likely to decline, and thus the freeze-thaw weathering that may produce many of the rocks will slow down. On the other hand, more frequent storms might also deliver more rocks to the playa.

Clearly climate change may affect the wind regime too, but trends in this parameter are not well-established, and in the absence of in-situ measurements on the playa, the overall effects of climate change on the playa rocks are open to some speculation..

7. Conclusions and Future Work

This paper has attempted to quantify the rates of supply and transport of rocks, and to show that numerical modeling may be a useful tool in understanding the playa's curious processes and highlights an apparent spatial and/or temporal disequilibrium between rock supply and removal. This paper would not have been possible without the pioneering work of Sharp and Carey, and in particular the diligent survey by Messina and Stoffer made available on the web. It is clear that repeat surveys, and in particular *complete* surveys, at intervals of a decade or less, would be useful in assessing the transport and supply rates. The utility of works prior to Messina's is compromised by their incompleteness, although prior to GPS satellite navigation (which made Messina's survey feasible with only 1~2 weeks of effort wand with no environmental impact from emplacing stakes) this would have been a demanding enterprise. Improvements in GPS equipment and the liberation of GPS from its Selective Availability (SA) limitations in 2000 makes surveys of adequate precision now feasible with inexpensive and readily-available equipment, and modern digital cameras with high-capacity memories also make photographic documentation easier than it was in 1996 so follow-up surveys should be possible with only a few days of effort.

As has always been the case, documentation of the meteorological conditions under which the rocks move would be an important contribution to understanding the process, and we have pointed out here that documentation of the conditions that drive the supply of the rocks would also be useful. Modern datalogging equipment may allow such measurements to be obtained unobtrusively, at least at the edge of the playa, consistent with National Parks policies. Such an effort poses an interesting measurement problem – if movements of some tens of meters occur at speeds of 0.5-1 m/s (Sharp and Carey, 1976), then movement lasts only a minute or so, in a period of about 3 years. In other words less than one in a million regularly-sampled datapoints will correspond to when movement was occurring : intelligent (e.g. event-driven) data sampling would clearly be a more efficient monitoring strategy.

Some modern investigations that might also be considered include ground-penetrating radar or similar methods to detect rocks that may be buried on the playa, radiocarbon dating of the mud at different depths (since cyanobacteria are present) and Be-10 measurements of the cosmic-ray exposure age of the rocks on the playa and cliff (e.g. Bierman and Nichols, 2004). It may be that within the National Park that not all of these investigations are permitted, however. Historical imagery that might document rock positions, but in particular the extent of the alluvial fan encroaching on the playa from the East and thus burying transported tocks, would also be useful.

While considering the playa rocks from a process perspective might be seen as threatening to the mystery of the rocks, in fact this study shows just what a special place the playa is. It must be hot and dry (to be a playa) but wet to be lubricated, it must be windy to blow the rocks, and it must be cold to supply them. There are few places indeed where a cliff rock source is so proximate to a playa basin that also meet these meteorological conditions, and it may be that these meteorological conditions are only met for a fleetingly short period in geological terms at this location.

Acknowledgements

This work was supported in part by the NASA Applied Information Systems Research program and the Cassini program (RADAR Team). My interest in Racetrack Playa was stimulated by a geology field trip visit from the Lunar and Planetary Lab, University of Arizona, led by my spouse Dr. Elizabeth Turtle. I am grateful to my collaborators, Brian Jackson and Jason Barnes, for stimulating discussions during subsequent visits to the playa.

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Figure 1. View from the southern cliffs on the Playa. The particular abundance of dark rocks on the bright playa near the cliffs is evident, supporting the notion that the cliffs are the source of most of the rocks.

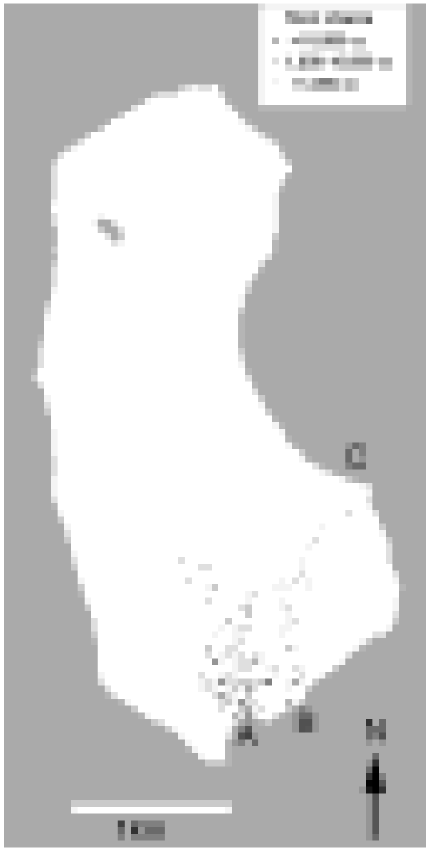

Figure 2. The distribution of rocks in 1996, denoted by rough size bins, on the playa, as documented by Messina (1998). The playa proper is shown in white – the grey patch at the northwest end of the playa is a monzonite bedrock island known as 'The Grandstand'. Rocks appear to come principally from bluffs A and B, and may be deposited particularly at area C.

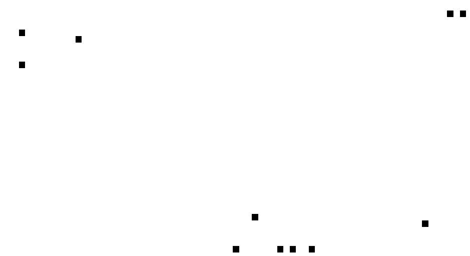

Figure 3. The size distribution of rocks measured by Messina (1998) plotted on double-logarithmic axes with √N error bars. The distribution is bounded by two linear segments with slopes proportional to the cube root and inverse two-thirds power of volume.

Figure 4. Model rock distributions. 130 rocks are deposited within 100m of the cliff (A) and allowed to move with rules specified in the text. With a 60o movement arc over the bearing range 345-45^o, the 'pulse' of rocks spreads and moves across the playa over 50 years (B). The first rocks meet the edge (and in the model, stay there) after 100 years (C) and most have left the playa by 150 years (D) to 200 years (E). Another set of model runs re-emplaces rocks at the cliff once they leave the playa : these runs in the lower panel show the rock distribution after 200 years, but with movement over different arcs bounded at 45^o (ENE). In (F) the arc is of zero width and all rocks move with a bearing of 45^o: transit time across the playa is short enough that a steady-state stream of rocks has formed. A similar pattern forms with 30 and 60^o movement arcs (G,H). With a 90^o arc (I) many rocks miss the eastern alluvial fan and are still propagating northward along the playa long axis – the initial 'pulse' of rocks is still distinct. If the arc is 120^o wide, almost all rocks are in the playa after 200 years, near the playa center.